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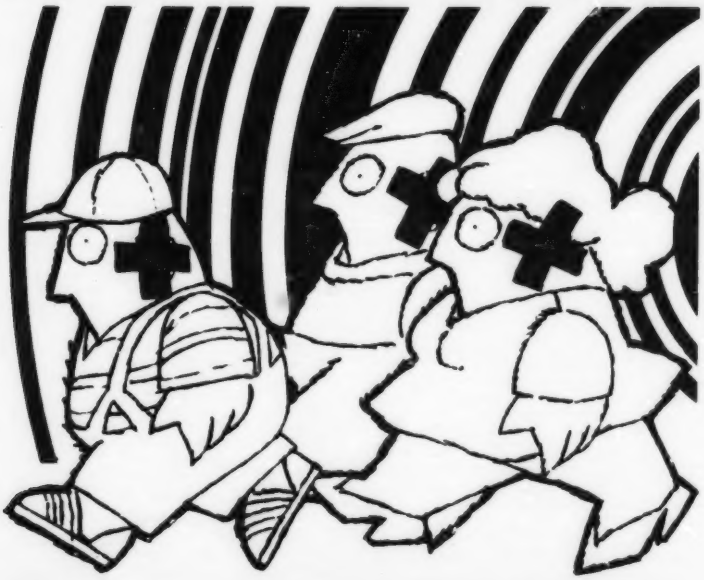

NOISE IS A HEALTH HAZARD

Alberta
ENVIRONMENT COUNCIL OF ALBERTA

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NOISE IS A HEALTH HAZARD

December 1980

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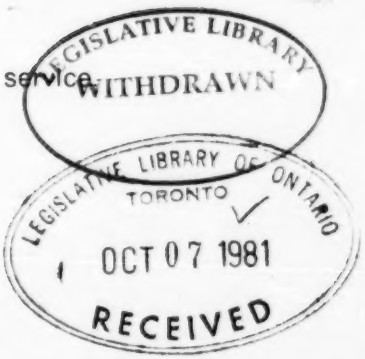

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Preface

In province-wide public hearings, the Environment Council of Alberta is offering everyone an opportunity to express their views and opinions on noise in Alberta. The information you provide will be used when the Environment Council gives its report to the Government of Alberta concerning the future direction of programs to deal with noise. In preparing for the hearings, the Environment Council has published a series of bulletins and brochures to improve the information base on several noise topics.

This bulletin, Noise is a Health Hazard, discusses the effects of exposure to noise on our health. Loss of hearing, the most significant effect, along with physiological, psychological, and behavioural effects are described. This report was prepared by the Occupational Health and Safety Division of Alberta Workers' Health, Safety and Compensation at the request of the Environment Council.

Although the Environment Council has undertaken to publish this report, the views expressed are those of the author and not necessarily those of the Environment Council. The Environment Council is not responsible for any facts or opinions presented or implied in this bulletin. What is endorsed is that the points raised are important and should be considered by Albertans while discussing noise.

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INTRODUCTION

The meaning of health, as embodied in the Constitution of the World Health Organization, is "health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity." Noise, therefore, is considered a health hazard, since it frequently interferes with an individual's state of well-being. Noise, by definition, is unwanted sound. Also, noise is considered a leading cause of hearing loss, making it a physical as well as psychological health hazard.

AUDITORY EFFECTS

Hearing loss induced by noise occurs predominantly within the industrial work environment. Initially, noise-induced hearing loss occurs at the higher pitches or frequencies, above those critical for speech reception. Consequently, the affected individual is unaware of any hearing loss. Continued exposure results in a progressive hearing loss and the pitches critical for speech become affected. By the time the exposed individual is clearly aware of having a hearing loss, a considerable amount of auditory damage has occurred. This damage is both handicapping and permanent. Susceptibility to noise-induced hearing loss varies greatly among individuals. At present, no way exists to determine in advance who is or is not susceptible. Prevention is the only solution for noise-induced hearing loss. Within the workplace, attempts are being made to preserve the worker's hearing through occupational hearing conservation programs. While off-the-job recreational pursuits and hobbies can also be a hazard to hearing, these noise sources are usually not consistent enough to cause a handicapping hearing loss.

Noise also has a profound impact in the area of speech interference. Such interference can constitute a safety hazard, create annoyance, and among children, interfere with development of auditory skills.

EXTRA-AUDITORY EFFECTS

Noise creates problems that go beyond auditory damage and interference with speech communication, and result in extra-auditory effects. Such extra-auditory problems are manifest in psychological and physiological reactions. Among the psychological effects are feelings such as annoyance, anger, and fear. Annoyance is probably the most pervasive phenomenon with respect to noise complaints. Such reactions are not always related to loudness. The psychological make-up of an individual and his attitude towards a given noise source may be the root cause of the annoyance.

Psycholgical reactions can result in physiological effects often associated with stress. These reactions may include increased blood pressure, abnormal heart rhythm, slow arterial flow and increased corticosteroids. It has been difficult to determine whether noise directly affects the autonomic nervous system,* resulting in some of the above-mentioned anomalies, or whether noise creates stress, which, in turn, results in the physiological abnormalities.

This bulletin discusses general physiological reactions and psychological and behavioural effects of noise. It also deals with the anatomy and physiology of the ear, and the physiological effects of noise on the auditory mechanism.

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*The autonomic nervous system is sometimes referred to as the involuntary nervous system over which a person does not have control. This system consists of the collection of nerves through which the abdominal organs, blood vessels, heart, glands, and some muscle receive their nerve control. Functions of the body controlled by this system include digestion, control of blood vessels, and reaction of the pupil in the eye to light conditions.

NOISE AND EXTRA-AUDITORY EFFECTS

THEORY OF EXTRA-AUDITORY EFFECTS

Noise activates the autonomic nervous system through three neurological processes:

1. the startle reflex which may be elicited from an unexpected loud noise;
2. the influence of the higher brain* on the autonomic system such as with fear of injury elicited by the sound of an oncoming truck;
3. the influence of the brain on the autonomic nervous system through such psychological reactions as annoyance, fear, and anger.

The human auditory mechanism is organized into two systems (Figure 1). The first system specifically transmits neural impulses from the ear to the brain through the traditional auditory pathway. The other system branches off the auditory pathway to the "activating-regulating" centre called the reticular formation, a special collection of nerve cells in the brain stem. The pathway spreads from the reticular formation to centres of the autonomic nervous system and into differing functional areas of the brain.

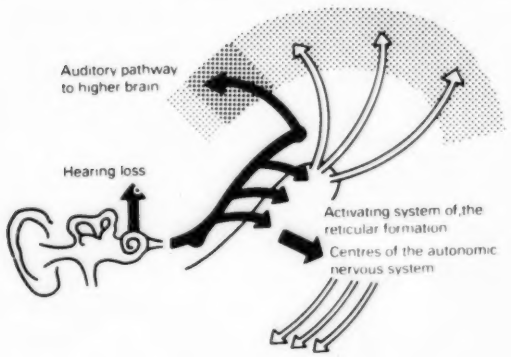
Auditory pathway to higher brain
Hearing loss
Activating system of the reticular formation
Centres of the autonomic nervous system

FIGURE 1: Human Hearing Mechanism

* The higher brain is the grey matter area, which controls such things as muscular co-ordination, intellect, and senses such as sight and hearing.

Research into extra-auditory response is divided into two schools of thought. The first is concerned with reflexive responses becoming conditioned, and the behavioural patterns dependent upon reinforcement of the response. The second, of more interest to the public, is concerned with noise stimulating the autonomic nervous system to the point of creating a stress, which in turn constitutes a health hazard physiologically. To believe that the autonomic nervous system causes over-arousal to the point of creating a health hazard assumes that the autonomic system will not adapt to the stimulus.

Researchers do not agree on this issue. The experimental situation itself could cause stress resulting in abnormal psychological data. Some studies documenting health problems, stress, absenteeism and other effects in noisy industries, as opposed to quieter industries, do not prove noise is the major culprit. Other factors creating stress, such as dust, fumes, and hazardous machinery, could be present within the noisy workplace, rather than just the noise itself. Hence, correlation is not proof of cause.

GENERAL PHYSIOLOGICAL REACTIONS

Despite problems with experimental design and measurement techniques, many research efforts consistently show physiological effects of noise. An increase in blood pressure resulting from exposure to high levels of noise is a common finding. Noise below levels considered hazardous to hearing has been found to result in significant physiological effects such as changes in blood pressure, heart rate and missed heart beats. Changes in hormone levels and blood cholesterol also occur.

High levels of noise might activate physiological defense mechanisms. Either the body successfully overcomes the influence of the noise-induced stress or breaks down from exhaustion. This

exhaustion may show itself in a variety of psychosomatic* syndromes such as ulcers and kidney problems.

Blood pressure and hearing loss among primitive people are rather interesting. A significant absence of hearing loss from aging (presbycusis) was noted among the Maben Tribe in Sudan. The Sudan is also a quiet environment undisturbed by civilization. A limited study of hearing among the Heikum of the Kalahari also revealed little hearing loss.

These studies naturally conclude that such observations result from a noise-free environment. Diet and generally stress-free environments were thought to be contributing factors to these findings, however. In fact, studies among other primitive people revealed hearing loss, and that hypertension (persistent and chronically high blood pressure) was a major variable in these findings. It is suspected that diet plays a key role in the development of hypertension among primitive people, all other factors held constant.

This research suggests a noise-free environment may not be a primary contribution to absence of hearing loss, but rather the absence of hypertension. This does not rule out the possibility of noise being an indirect factor in presbycusis among people in modern urban environments. Noise levels above and below that considered hazardous to hearing do produce stress that manifests itself in changes of blood pressure, as indicated earlier. If chronically high blood pressure resulting from dietary habits reduces hearing ability, it can be speculated that elevated blood pressure from noise-related stress causes hearing loss, independent of or in addition to the traditional industrial hearing loss. To date, however, chronically high blood pressure in the urban environment has not been successfully related to exposure to noise.

*Psychosomatic pertains to the influence of the mind or higher functions of the brain (emotions, fears, desires, etc.) upon functions of the body in relation to disease.

INTERSENSORY EFFECTS

Steady noise at high levels can affect non-auditory sensory functions, although exposure to noise levels sufficient to cause these effects are relatively rare in Alberta. In fact, regulations in Alberta simply prohibit workers being exposed to noise levels of 115 decibels* when not being protected in some way.

Exposure to noise louder than 115 dBA can reduce the ability of the eye to focus, narrow visual fields and create a deficiency of color perception (red). Workers with a history of long-term exposure to noise report loss of touch and feeling. In fact, moderately high levels of noise have been used as an anesthetic.

Higher noise levels could result in reduced safety margins in risky jobs. The noisest jobs generally have the highest rate of accidents and injuries.

EFFECTS ON SLEEP

Noise often intrudes on sleep, unnecessarily arousing the body's biological alerting mechanisms. The effects of sleep deprivation upon day-time performance are not clearly known. Prolonged lack of adequate sleep becomes a health problem not to mention the effect on an individual's disposition.

The extent to which noise intrudes is related to age, gender, stages of sleep, and on the sound itself. Apparently, 50 percent of young adults will be awakened by sound levels of about 55 dBA. The sound level for infants is about 65 dBA. Older adults are relatively easy to awaken, are more easily disturbed, and have much more difficulty returning to sleep.

*Sound is measured in units called decibels (dB). The threshold of hearing for a normal, young person is 0 dB. A very loud sound of 120 dB would be painful to hear. The notation dBA refers to sound levels measured by a meter in a way similar to our subjective impression of sound.

PSYCHOLOGICAL AND BEHAVIOURAL EFFECTS OF NOISE

ANNOYANCE

Annoyance is a very common non-auditory effect of exposure to noise and has major psychological ramifications. Annoyance probably influences the autonomic nervous system. This influence can reach a point among some people where physiological stress contributes to ill health.

Despite the psychological connotations of noise, clearly physical attributes of sound have been found to influence annoyance.

1. Single-frequency tones are more annoying than bands of frequencies.
2. Higher-frequency sounds are more annoying than lower-frequency sounds.
3. Increased intensity of the offending noise; a 10 dB increase in intensity doubles the magnitude of the annoyance response.
4. Variable sounds are more annoying than steady sounds.

The connotation a sound carries may cause annoyance out of proportion to its acoustical qualities. Also, an attitude towards a given source may do the same. A person who loves dogs, for example, is likely to tolerate a barking dog more than a person who hates or fears dogs.

TASK PERFORMANCE

The effects of noise on task performance have been widely studied with variable results. The nature of the acoustical environment and the attitude and psychological make-up of the person involved play a significant role in results. Generally, transient, irregular noise interferes with tasks that are fast-paced and complex. One study involving the solving of complex puzzles found that the noise levels, 108 dB versus 50 dB, was of little consequence in the outcome. The key variable appeared to be whether or not the subjects expected the noise.

AUDITORY SKILLS

The effect of noise on auditory skills is not strictly an extra-auditory effect, although it can be considered to influence behaviour.

Background noise levels that do not interfere with speech perception of adults do, in fact, influence significantly the speech perception capabilities of infants. This is likely due to a lack of listening experience, language skills, central nervous system maturation, and so on. Exposure to high levels of noise for a prolonged period will likely have unfavourable effects upon speech, language acquisition, and reading skills of children. It has long been suspected that fluctuating hearing, such as occurs with intermittent ear infections, contributes to auditory perceptual defects among children.

One study examined the effects of traffic noise on speech and reading skills among elementary school children living in a large apartment building. Sound levels outside the apartment were 84 dBA at ground level, down to 55 dBA on the 32nd floor: those inside the apartments ranged from 71 dBA down to 50 dBA. The findings of the study clearly indicated that auditory discrimination was adversely affected by noise. Auditory discrimination ability is an important skill in reading achievement. Although children may learn to filter out the noise, deficits in both verbal and auditory skill can be anticipated.

SPEECH INTERFERENCE

Measuring speech intelligibility, considering variables such as noise levels, speech discrimination materials, and noise spectrum, is a major subject in work on speech interference. This topic is quite technical and is auditory/communication oriented.

Speech interference frequently creates annoyance and can be a safety hazard. Working in a noisy

environment with inadequate communication systems can lead to workers having such hoarse voices, that they require corrective surgery. Thirty percent of those workers who return to their noisy environment after surgery suffer from the problem again.

NOISE IN THE AUDITORY MECHANISM

ANATOMY AND PHYSIOLOGY OF THE AUDITORY MECHANISM

In order to discuss noise and its effects on the auditory mechanism, a brief description of that mechanism is required.

Traditionally, the ear is divided into three basic portions or anatomical divisions: external, middle, and inner ear.

External Ear

What most of us consider the ear is the auricle or pinna (Figure 2). The function of the pinna is simply to gather and funnel sound waves through the external auditory canal to the eardrum. The external auditory canal is that part of the ear, into which we are told never to put anything smaller than our elbow. The canal runs horizontally for 2.5 cm from the pinna to the eardrum. The outer portion of the canal contains stiff hairs that secrete ear wax. The hairs and wax keep dirt and insects away from the eardrum.

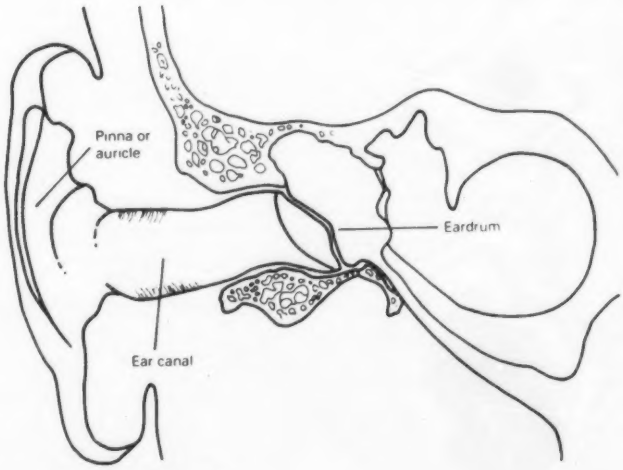

FIGURE 2: Outer Ear

Middle Ear

The middle ear consists of the mastoid air cells, the sound conducting mechanism and the eustachian tube (Figure 3). The sound conducting mechanism consists of the eardrum and behind it an air-filled cavity. Within this cavity occur three of the smallest bones of the body, (Figure 4) the malleus, incus, and stapes. Collectively they are known as the ossicles. These ossicles are supported by ligaments and two muscles, the tensor tympani, and the stapedial muscles. The stapedial muscle,

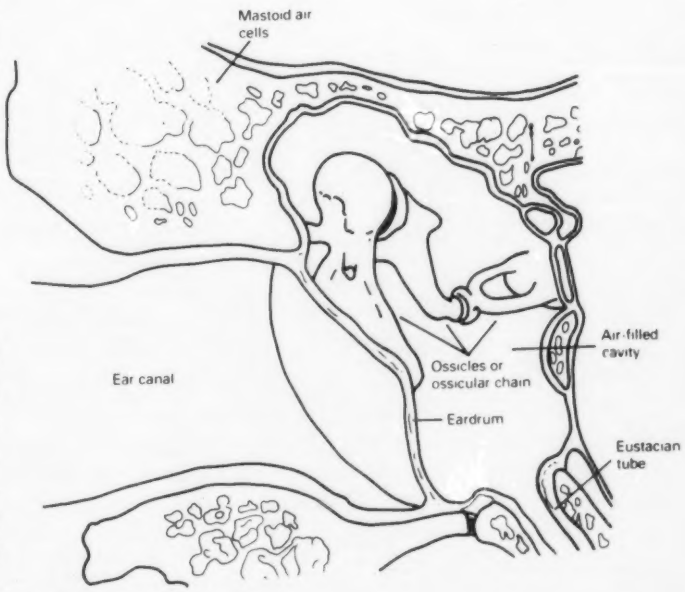

FIGURE 3: Middle Ear

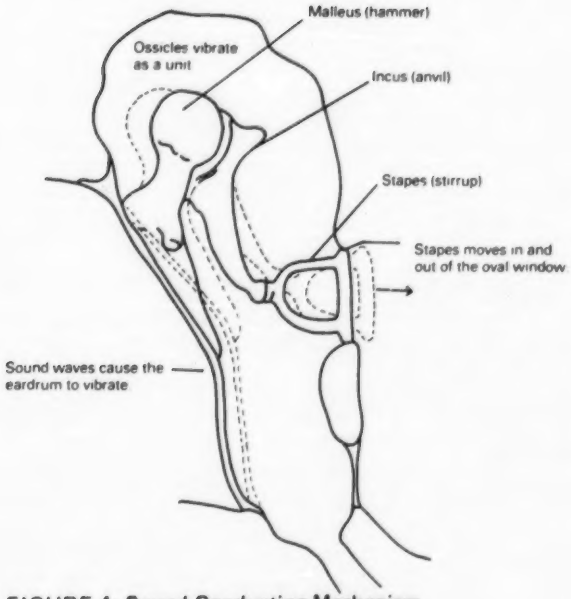
Malleus (hammer)
Ossicles vibrate as a unit
Incus (anvil)
Stapes (stirrup)
Stapes moves in and out of the oval window
Sound waves cause the eardrum to vibrate

FIGURE 4: Sound-Conducting Mechanism

apparently the most responsive to noise, together with the tensor tympani, stiffen the eardrum and ossicles. This action reduces the transmission of noise, particularly for lower-frequency sounds. The middle ear space is ventilated by the eustachian tube, which is normally closed. The eustachian tube runs from the middle ear to the back of the throat and, when open, equalizes pressure on either size of the eardrum.

The middle ear transfers sound energy from the outer ear to the inner ear. As the eardrum vibrates, this motion is transferred across the ossicles. The stapes moves back and forth at the oval window in a piston-like fashion, in sequence with and proportional to the frequency and intensity of the sound. The vibrating, mechanical motion of the eardrum is thus transmitted to the inner ear.

At the same time, the sound is amplified due to the difference in the size of the eardrum versus the oval window, similar to a magnifying glass, which concentrates enough heat to start a fire. The ossicles also act as levers, which increase the sound energy.

Inner Ear

Within the temporal bone of the skull is a series of channels so complicated they are known as a labyrinth. This bony labyrinth (Figure 5), filled with a watery fluid known as perilymph, is composed of the semi-circular canals (balance mechanism) and cochlea (hearing mechanism). These two parts are joined by the vestibule. Within the perilymph is another labyrinth, the membranous labyrinth (Figure 6), which is filled with a fluid called endolymph. The membranous labyrinth consists of the balance organs and the cochlear duct (Figure 7). A primary function of the ear is to give people balance. The balance and auditory systems interrelate with respect to certain medical pathologies. Results of hearing tests frequently suggest why a patient may be dizzy.

Figure 8 is a cross-section of the cochlea and cochlear duct. Four rows of hair cells rest on the basilar membrane. These cells are covered and embedded in a tectorial membrane, which in turn lies under the vestibular membrane. The latter membrane is displaced by the movement of the perilymph causing a sheering action on the tectorial surface, which drags the hair cells that are actually attached to the nerve endings. The sheering action sets up electrical impulses, which are coded and sent to the brain. Many

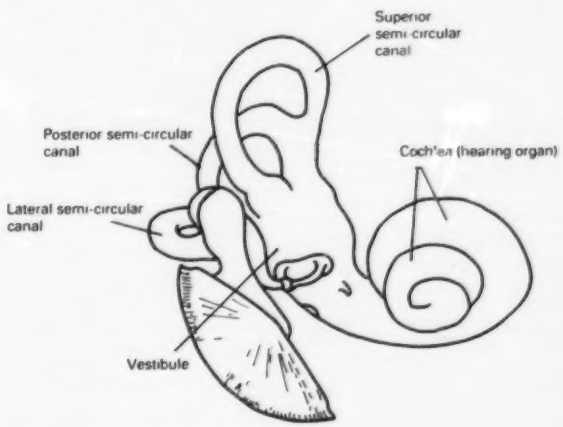

FIGURE 5: Bony Labyrinth

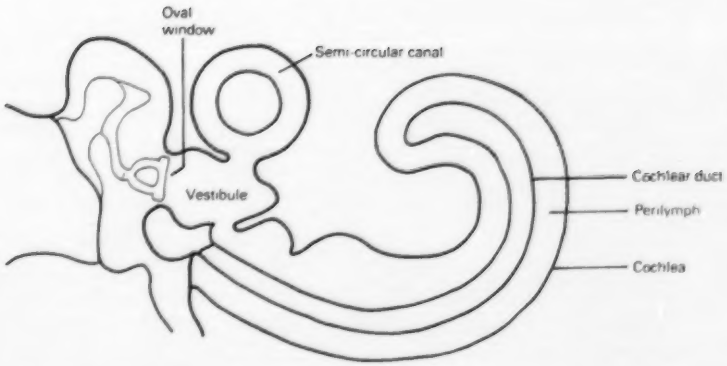

FIGURE 6: Cochlear Duct

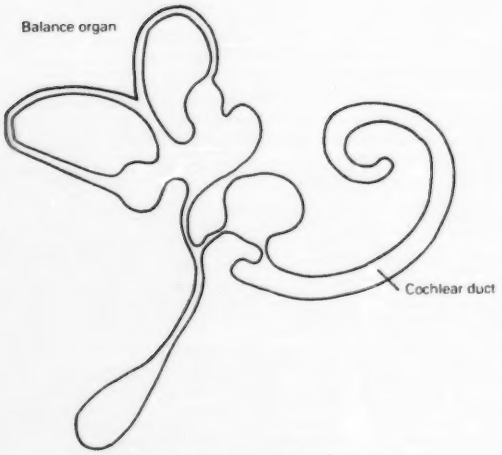

FIGURE 7: Membranous Labyrinth

theories exist as to how this process occurs. It is known that the cochlea is frequency (pitch) sensitive. Higher frequencies are detected at the base of the cochlea (close to the stapes). The lower frequencies are detected at the apex of the cochlea. Of the four rows of hair cells, three are referred to as external hair cells. The single row closest to the internal spiral sulcus (Figure 8) is referred to as inner hair cells. The external hair cells are the most sensitive to noise damage.

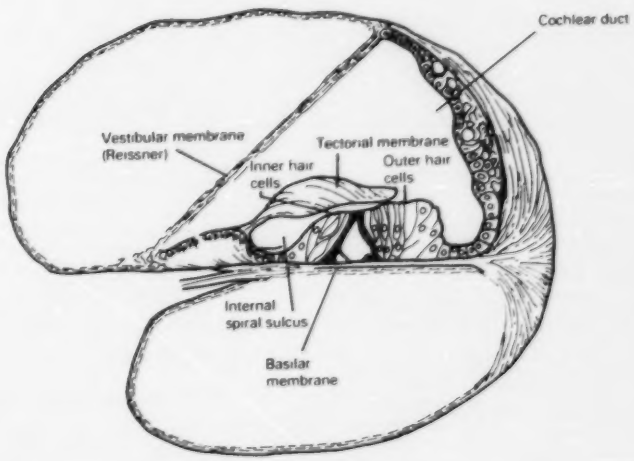

FIGURE 8: Cross-section of Cochlea and Cochlear Duct

NOISE AND AUDITORY DAMAGE

Sound is created by vibration or pressure waves moving through the air. The pattern of their movement is similar to the effect of dropping a pebble into water. The waves created radiate outward in all directions from the source.

Sound has two important characteristics, intensity and frequency. Frequency is basically pitch. A sound wave is similar to a slinky toy. When the toy is pressed together it is compressed, and when pulled apart it is expanded. One single compression and expansion is a cycle. The number of cycles per second (cps) is sensed by the ear as pitch. The higher the cps the higher the pitch. Today cps is usually designated as hertz (Hz).

The frequency range of the normal human ear is 20 Hz to 20,000 Hz. The ear is not equally sensitive to all frequencies; for example, more energy is required to stimulate the ear at 125 Hz and 8,000 Hz than at 2,000 Hz. The frequencies most required to understand speech occur between 500 Hz and 3,000 Hz. These frequencies are within the range of frequencies most sensitive to sound and must be protected from the adverse effects of noise.

Intensity is generally sensed as loudness, although the two are not identical due to the differential

sensitivity of the ear across all frequencies. Intensity is a physical description of the amount of energy or pressure; loudness is how the ear perceives that pressure.

Sound is measured using an instrument known as a sound-level meter. Sound pressure waves are sensed by the microphone and converted to an electrical signal which is amplified. This signal activates an output meter giving the reading. In addition, sound-level meters have weighting networks which are biased towards certain frequency bands. The weighting networks include A, B, C, and D. The A weighted network discriminates against frequencies below 1000 Hz. This network has been found to be the best indicator of noise hazard, and the best reflection of an individual's subjective impression of most sound or noise. Consequently, when studying noise, measurements are usually made in dBA.

As mentioned earlier, most noise-induced hearing loss occurs within the industrial environment. Noise in the workplace can be sufficiently intense and the exposure consistent enought to damage the ear permanently. The initial effect of noise-induced hearing loss is found between 4,000 Hz to 6,000 Hz, although 3,000 Hz is sometimes affected as well. This gives the audiogram (a chart recording the hearing test) a distinct notched appearance as shown in Figure 9.

Since the initial effects of intense noise occur above the crucial speech frequencies, the individual is unaware of his susceptibility to the exposure. Repeated unprotected exposure will result in a deepening and widening of that notch, which eventually affects the crucial speech frequencies as shown in Figure 10.

By the time the individual is aware something is wrong, a considerable amount of hearing is lost. Noise-induced hearing loss is irreversible and cannot be treated medically. Hearing testing is recommended for people exposed to noise. Their susceptibility to the exposure can easily be detected early enough allowing protective action prior to serious hearing loss developing. While susceptibility

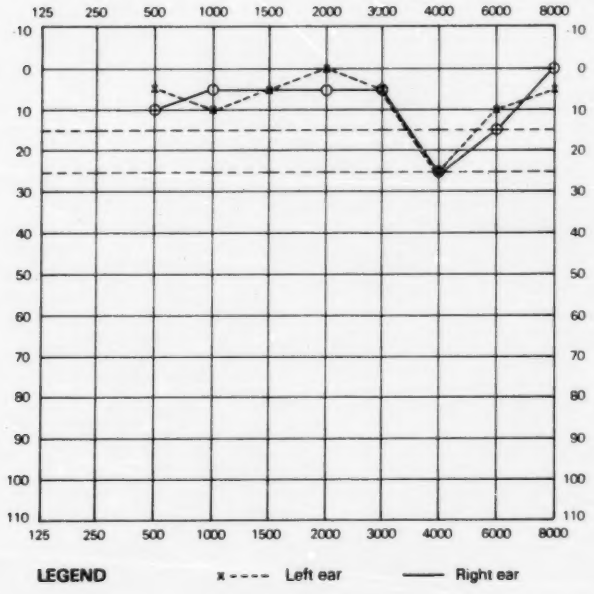

FIGURE 9: Early Noise-Induced Hearing Loss
Note the high frequency notch

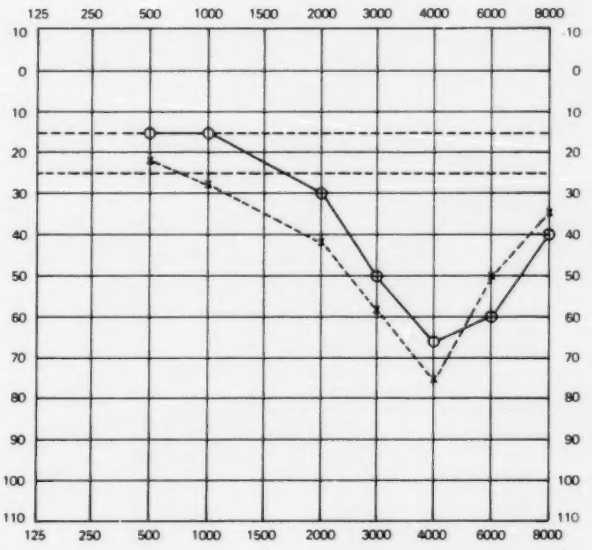

FIGURE 10: Advanced Noise-Induced Hearing Loss
Note the high frequency notch

to noise varies with individuals, the only way to identify that susceptibility is to test hearing, as early effects of exposure will show up on the test chart.

Several theories have been advanced as to why noise is so damaging between 4,000 Hz to 6,000 Hz (the notch on Figure 9). One school of thought, not so widely accepted at this time, is that the 4,000 Hz region of the cochlea is more susceptible to damage than other portions. As an example, blood supply to that area is supposedly poor. Another school of thought, the mechanical theory, has taken precedence over the susceptibility theory. Mechanical stress, during auditory stimulation, is considered the greatest at the portion of the basilar membrane related to 4,000 Hz and 6,000 Hz.

Other factors include the nature of occupational or environmental noise. Industrial noise tends to be broad band with equal energy across the band width. The maximum effect noted with this type of noise occurs between 3,000 Hz to 6,000 Hz. With narrower bands of noise, the maximum effect occurs ½ to 1 octave above the upper cut-off frequency of the noise. An octave is double the value under consideration, that is, 2,000 Hz is an octave above 1,000 Hz while 4,000 Hz is an octave above 2,000 Hz. Therefore, if a noise has an upper cut-off of 2,000 Hz, the maximum effect will occur between 3,000 Hz to 4,000 Hz. Those frequencies below 1,000 Hz occurring within a given noise are attenuated somewhat by the action of the stapedial and tensor tympani muscles (acoustical reflex). Another factor of the notch is the natural resonance of the ear canal which results in sound being amplified in the 2,000 Hz to 3,000 Hz region. Auditory stimulation in this area shows the greatest effect on hearing in the 4,000 Hz to 6,000 Hz region.

Given that most noise known to create hearing loss has significant energy between 1,000 Hz to 3,000 Hz or is broad band with equal energy across all frequencies, we expect to see hearing loss develop in the 4,000 Hz to 6,000 Hz region. Theoretically, intense and prolonged low frequency stimulation, fatiguing the acoustic reflex, would result in notches occurring elsewhere on the audiogram. As a matter of fact, research has demonstrated that low frequency stimulation shifts hearing at 500, 750 and 1,000 Hz with little effect being noted elsewhere.

TEMPORARY AND PERMANENT HEARING LOSS

The ears frequently will ring after excessive exposure to noise, and sound is obviously muffled. After a time, however, the hearing appears to return to normal. This is a description of temporary threshold shift (TTS), a temporary alteration of hearing sensitivity. TTS in animals and humans can be induced in a laboratory. Through these experiments, much has been learned about various types of noise and its effect upon hearing. At one time, the amount of TTS experienced was considered an indicator of a given individual's susceptibility to noise. This relationship in fact has been difficult to establish. It is now widely held that TTS and permanent threshold shifts (PTS) are indirectly related.

The effect of a given noise relative to either PTS or TTS varies among individuals. For reasons not yet clearly established, some people are much less susceptible to the effects of noise, particularly at the lower intensity and exposure levels.

Permanent hearing loss or PTS results when exposure causes structural damage within the cochlea, likely the damage or loss of external inner hair cells. With sufficient intensity, however, other structural damage may also occur. By far the majority of PTS results from repeated exposure to lower intensity noise, the effects of which are first unnoticed and irreversible.

As mentioned above, the initial effect occurs between 4,000 Hz to 6,000 Hz with the area of damage spreading to the lower frequencies. The maximum hearing loss from a given noise will occur during the first 5 to 10 years of exposure to it. Permanent hearing loss appears to occur

when the hair cells do not get sufficient rest to recover from the effects of TTS. The hair cells will bend over and recover from one or a few episodes of noise exposure, like blades of grass when we step once in one place. But after repeated exposure, like walking on the same grass over and over, the hair cells will not bend back and permanent hearing loss results. Noise-induced hearing loss typically affects both ears equally although there are some exceptions, such as in farming and shooting.

NOISE-INDUCED HEARING LOSS: ITS EFFECTS ON SPEECH DISCRIMINATION

A noticeable hearing loss from exposure to noise is said to be one of the most handicapping of auditory disorders. Loss of the ability to understand speech, abnormal growth of loudness (painful hearing), a frequent annoying ringing sound in the head, and poor pitch discrimination are the primary symptoms that can occur with noise-induced hearing loss.

Speech is composed of vowels and consonants. Vowels are low pitched, voiced, and have substantial power. Consonants, for the most part, are nothing more than air flow that is modified with the tongue and lips. The energy of consonants lies primarily in the higher frequencies and is much influenced by decreased intensities as would occur with high-frequency hearing loss. Consonants are the key to understanding speech. Since the vowels are relatively unaffected by high-frequency hearing loss, a common complaint is: "I hear speech, but I don't understand it."

The physiological effect of noise upon the inner ear is also quite significant. As mentioned earlier, four rows of hair cells are present within the cochlea. The inner-most row consists of about 3,500 cells. The outer three rows, composed of nearly 20,000 cells, are most susceptible to damage from noise.

The two groups of hair cells appear to have different, but mutually supportive roles in human hearing. It has been found that 95 percent of the nerves carrying sensory information from the inner ear to the higher neural centres in the brain (afferent) originate from the inner hair cells. Nerves transmitting information back from the mid-brain to the cochlea (efferent) primarily terminate or synapse with the outer hair cells. Specifically, 80 percent of the efferent nerves synapse with the outer hair cells while 20 percent do so with the inner hair cells. It is apparent, therefore, that these two regions of the cochlea have different functions, a theory that has been found credible in animal studies.

Most significant for our purpose is the function of the outer hair cells. The brain sends messages to the ear through the efferent fibres which have a suppressive effect on hearing. This results in a phenomenon known as critical band width. If the width of a signal goes beyond a critical band of frequencies, it will seem louder than when it is within that critical band, even though intensity remains unchanged. In short, broad band noise sounds louder than narrow band noise. Suppression acts as a filter. The narrower the filter, the more noise is restricted. Conversely, the wider the filter, the poorer the ear's ability to recognize pitch components of a signal. Filtering then acts as the ear's fine tuning device.

Loss of the suppressive effect occurs primarily when the external hair cells are damaged. This explains the three common symptoms of noise-induced hearing loss; painful hearing, poor discrimination of speech, particularly in noisy surroundings, and poor pitch discrimination. Pure tone audiometry, or a hearing test, is primarily a test of inner hair cells by virture of afferent nerve fibres which carry the pure tone stimulus from the ear to the brain. Although audiometry also detects damage to external hair cells, it is not sensitive enough to depict the entire scope of auditory damage. Therefore, pure tone results are not always a reliable indicator of a person's ability to communicate adequately.

The physiological function of the inner ear and the limits of hearing testing to detect early external

hair cell damage has been a key rationale for those promoting more stringent noise-exposure limits for an eight-hour day. This loss of filtering effect from damage to external hair cells is a major reason why noise-induced hearing loss is so damaging. Once again, this is a handicap that cannot be medically treated. Also, it is not particularly amenable to correction by a hearing aid.

ULTRASONIC AND INFRASONIC

Ultrasonic and infrasonic sound and its effect upon man have recently been some cause for concern. Although little is written on the subject, it appears the effect of these exposures are limited. Ultrasonic frequencies are above 20,000 Hz. Jet engines, high-speed drills and cleaning devices are sources of ultrasonic sound. People working near jet engines have complained of fatigue, nausea, and headaches. These stress-type symptoms may be elicited by the spectral content and unpleasant tonal characteristics of the subharmonic sound. One study of ultrasonic sound revealed no TTS. Consequently, it was concluded ultrasonic sound will not cause hearing loss. Most authors, however, caution the possible effect of subharmonic sound falling within the range of human hearing.

Usually ultrasonic waves are absorbed quickly by air and, therefore, are of significance only close to the source. Some interesting phenomena occur with respect to ultrasonics and their subharmonics. For instance, high frequency sound energy can actually create heat to char clothes. Also a bare hand with fingers apart is unaffected by sound of 160 dB. If the fingers touch, however, the acoustic friction quickly causes painful amounts of heat. These high intensities are laboratory induced, however, and rarely occur outside the experimental situation.

Infrasonic sound (below 20 Hz) and vibrations cause fellings of discomfort if the stimulus is sufficiently intense. Infrasonics and vibration both can cause disorientation and nausea. Sufficient exposure to vibration may cause damage to certain body tissues. Infrasonics of greater than 120 dB sound pressure may cause dizziness.

SUMMARY

In summary, auditory effects of noise, that is, the effect of noise on hearing and on speech communication, are fairly well documented and concrete. Noise-induced hearing loss can significantly affect one's ability to communicate thus creating a handicap. Speech interference of course creates annoyance, can be a safety hazard, and, in the case of children, may lead to possible learning disability.

Extra-auditory effects of noise are not so clearly understood. Basically, the question centres upon whether or not noise affects the autonomic nervous system which in turn causes physiological anomalies such as high blood pressure and increased heart rate with stress subsequently arising. The other side of the coin, however, is that an individual's psychological makeup or his attitude towards a given noise source results in stress which in turn may cause physiological anomalies. Further research is needed in order to clarify this question.